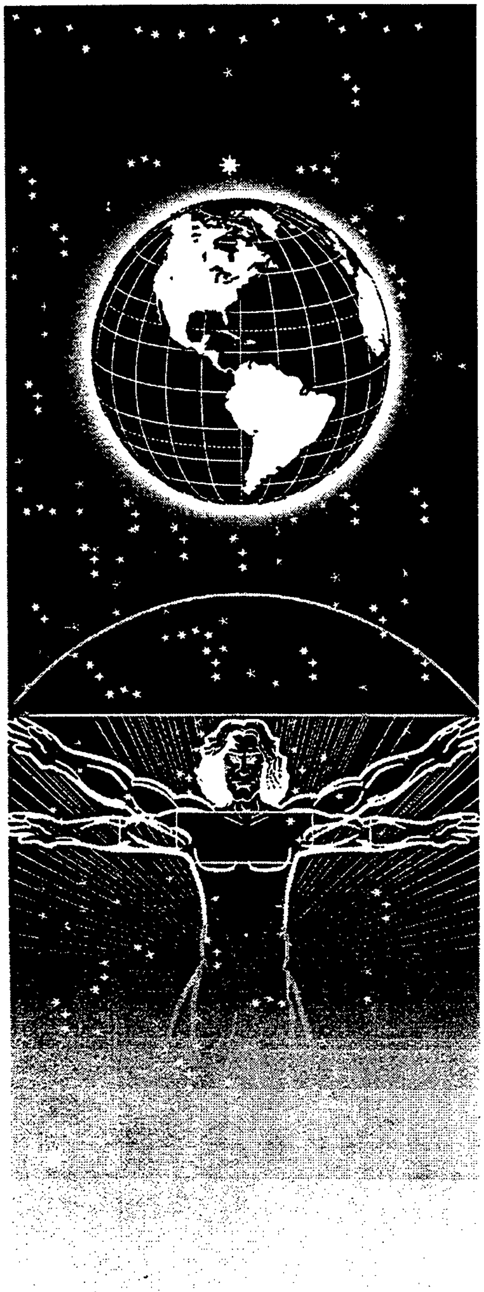
AFRL-HE-AZ-TR-1998-0078



UNITED STATES AIR FORCE RESEARCH LABORATORY

TRANSFER OF TRAINING EFFECTIVENESS IN FLIGHT SIMULATION: 1986 TO 1997

Thomas R. Carretta

Training Effectiveness Branch
Warfighter Training Research Division
7909 Lindbergh Drive
Brooks AFB TX 78235-5352

Ronald D. Dunlap

Air Warrior Training Branch
Warfighter Training Research Division
6001 South Power Road, Building 558
Mesa AZ 85206-0904

September 1998

AIR FORCE MATERIEL COMMAND
AIR FORCE RESEARCH LABORATORY
HUMAN EFFECTIVENESS DIRECTORATE
WARFIGHTER TRAINING RESEARCH DIVISION
6001 South Power Road, Building 558
Mesa AZ 85206-0904

NOTICES

Using Government drawings, specifications, or other data included in this document for any purpose other than Government-related procurement does not in any way obligate the US Government. The fact that the Government formulated or supplied the drawings, specifications, or other data, does not license the holder or any other person or corporation, or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

THOMAS R. CARRETTA
Project Scientist

DEE H. ANDREWS
Technical Director

LYNN A. CARROLL, Colonel, USAF
Chief, Warfighter Training Research Division

Please notify AFRL/HEOP, 2509 Kennedy Drive, Bldg 125, Brooks AFB, TX 78235-5118, if your address changes, or if you no longer want to receive our technical reports. You may write or call the STINFO Office at DSN 240-3877 or commercial (210) 536-3877, or e-mail Shirley.Walker@platinum.brooks.af.mil

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1998	Final - January 1997 to December 1997

4. TITLE AND SUBTITLE

Transfer of Training Effectiveness in Flight Simulation: 1986 to 1997

5. FUNDING NUMBERS

PE - 62202F
PR - 1123
TA - B1
WU - 01

6. AUTHOR(S)

Thomas R. Carretta
Ronald D. Dunlap

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Training Research Division, Training Effectiveness Branch
7909 Lindbergh Drive
Brooks Air Force Base TX 78235-5352

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Training Research Division
6030 South Kent
Mesa AZ 85212-0904

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AFRL-HE-AZ-TR-1998-0078

11. SUPPLEMENTARY NOTES

Air Force Research Laboratory Technical Monitor: Dr Thomas R. Carretta, (210) 536-3956, DSN 240-3956

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The purpose of this report was to review recent studies regarding the effectiveness of flight simulators as augmentation for "hands-on" flying training. Simulation-based training has been proposed to reduce costs, extend aircraft life, maintain flying proficiency, and provide more effective training, especially in areas difficult to train in operational aircraft. A review of the literature from 1986 to 1997 identified 67 articles, conference papers, and technical reports regarding simulator flying training and transfer. Of these, only 13 were related directly to transfer of training from the simulator to the aircraft. Studies of simulator effectiveness for training landing skills constituted a majority of the transfer studies, although a few examined other flying skills such as radial bombing accuracy and instrument and flight control. Results indicate that simulators are useful for training landing skills, bombing accuracy, and instrument and flight control. Generally, as the number of simulated sorties increases, performance improves, but this gain levels off after approximately 25 missions. Further, several studies indicate that successful transfer may not require high-fidelity simulators or whole-task training, thus reducing simulator development costs. Evaluation of this literature is difficult for many reasons. Typically, researchers fail to report sufficient detail regarding research methods, training characteristics, and simulator fidelity. In addition to these methodological concerns, there is a lack of true simulator-to-aircraft transfer studies involving complex pilot skills. This may be due to problems such as inadequate simulator design, cost, and availability, and access to simulators in operational flying units. Future directions in simulator transfer of training are discussed.

14. SUBJECT TERMS

Flight simulation; Flight simulators; Simulation-based training; Simulator effectiveness; Simulator transfer of training; Training effectiveness; Transfer of training

15. NUMBER OF PAGES

17

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION ABSTRACT
Unclassified	Unclassified	Unclassified	UL

CONTENTS

	Page
INTRODUCTION	1
TRANSFER OF TRAINING STUDIES	1
Early Studies: 1957 to 1986	1
Recent Studies: 1987 to 1997	1
Landing Skills	2
Radial Bombing Accuracy	3
Instrument and Flight Control	3
PROBLEM AREAS	4
FUTURE DIRECTIONS	4
REFERENCES	5
APPENDIX: RELATED REFERENCES	7

PREFACE

This effort was conducted under Work Unit 1123-B1-01, Pilot Selection and Classification Support, which is dedicated to research into the selection and classification of U.S. Air Force aircrew personnel. Send written correspondence to AFRL/HEAB, 7909 Lindbergh Drive, Brooks AFB, TX 78235-5352. Send electronic mail to carretta@alhrm.brooks.af.mil.

TRANSFER OF TRAINING EFFECTIVENESS IN FLIGHT SIMULATION: 1986 TO 1997

INTRODUCTION

Over the past several decades, researchers have sought to determine the effectiveness of flight simulators as augmentation for "hands-on" flying training. Simulators have been proposed for use to save money, extend the life of the aircraft, maintain proficiency when not performing "hands-on" flying, and provide more effective training especially in areas difficult to train in operational aircraft (e.g., emergency procedures). The purpose of this report is to review and summarize the literature from 1986 to 1997 regarding the transfer of training from the simulator to the aircraft. Sixty-seven articles, conference papers, and technical reports regarding simulator flying training and transfer were identified. Of these, only 13 were related directly to transfer of training. For the interested reader, the Appendix contains references regarding the 54 flying training studies that were not directly related to transfer of training.

TRANSFER OF TRAINING STUDIES

Early Studies: 1957 to 1986

Hays, Jacobs, Prince, and Salas (1992) reviewed the pilot training literature from 1957 to 1986. Their initial survey included 247 journal articles, book chapters, and technical reports regarding training effectiveness. Of these, only 26 studies included information sufficient to be included in a meta-analysis regarding transfer of training in a flight simulator to operational aircraft equipment. Of the 26 studies, 19 involved jet aircraft and 7 involved helicopters. The meta-analysis revealed several trends that were not readily apparent from the individual studies. First, simulators consistently led to improved training effectiveness for jet pilots relative to training in the aircraft only. However, this was not true for helicopter pilots. Second, motion cueing was not found to add to training effectiveness for jet pilots and, in some instances, may have led to less-effective training. Motion cueing was not examined for helicopter pilots due to the small number of studies. Finally, training effectiveness was strongly influenced by the amount and type of training given and by the type of task trained. For instance, simulators were more effective for training takeoff, approach to landing, and landing than they were for the combination of all pilot tasks.

Recent Studies: 1987 to 1997

Since the mid-1980s, several studies have examined transfer and/or quasi-transfer of training of flying skills (Lintern & Garrison, 1992; Lintern, Roscoe, Koonce, & Segal, 1990; Lintern, Roscoe, & Sivier, 1990; Lintern, Sheppard, Parker, Yates, & Nolan, 1989; Lintern, Taylor, Koonce, Kaiser, & Morrison, 1997; Lintern, Thomley-Yates, Nelson, & Roscoe, 1987; Pfeiffer, Horey, & Butrimas, 1991; Taylor, Lintern, & Koonce, 1993; Westra, et al., 1986; Wightman & Sistrunk, 1987). Although simulators have been used to train several aspects of

flying (e.g., takeoff, landing, instruments, control), by far, the most frequently investigated use of simulators was for training landing skills.

Landing Skills. Consistent with meta-analytic results found in Hays et al. (1992), several subsequent studies have shown simulators to be effective for training landing skills. Westra et al. (1986) examined the effects of simulator design features on the training effectiveness of the skill required for landing on aircraft carriers. They compared night (i.e., low detail) versus daytime (i.e., high detail) scenes crossed with wide versus narrow field of view. Pilots received 20, 40, or 60 simulator trials. Results indicated that neither scene detail nor field of view influenced effectiveness of transfer from the simulator to the aircraft. However, pilots receiving 40 or 60 simulator trials exhibited better landing skills than those who received only 20 trials.

Lintern and his colleagues have conducted several studies investigating the effects of the amount of simulator time, scene detail, crosswind, field of view, display orientation, augmented feedback, and bank control. For example, Lintern, Roscoe, Koonce, and Segal (1990) examined transfer of landing skills from a flight simulator to an aircraft in early flight training. One group of beginning flight students was given two sessions of practice of landing skills in a simulator before starting landing practice in the aircraft. A control group was given no practice in the simulator prior to practice in the aircraft. Results indicated that the experimental group required 1.5 fewer pre-solo flying hours than the control group. This reduction in flying hours, whether military or civilian, could lead to considerable savings.

Several follow-on studies were conducted to examine the effects of different simulator attributes on the transfer of landing skills. Lintern, Roscoe, and Sivier (1990) investigated effect of scene detail (pictorial vs. symbolic), display orientation (outside in or inside out), bank control order (first order or zero order), crosswind (present or absent), command guidance (constant, adaptive, or no augmentation), and flight path prediction (constant, adaptive, or no augmentation) on transfer of landing skill in the simulator. The final criterion was a "conventional inside out pictorial contact display, normal simulator control dynamics, and a 5-knot crosswind" (p. 299). They found that pictorial displays were more effective than symbolic displays and normal bank control order was better than reduced control for producing transfer.

Lintern and Garrison (1992) examined transfer effects of scene detail (high pictorial, low pictorial, or symbolic) and level of crosswind (zero, moderate, or high) on landing performance in a simulator. Participants were assigned to one of nine training conditions. The final performance criterion consisted of a high pictorial, moderate crosswind, simulation. Neither scene detail (high vs. low pictorial) nor level of crosswind had a significant effect on transfer. Consistent with Lintern, Roscoe, and Sivier (1990), pictorial displays led to better transfer than symbolic displays.

Lintern et al. (1997) investigated effects of scene detail (low or moderate), visual augmented guidance (off, constant, or adaptive), and number of landing training trials (0, 24, 48, or 72) in the simulator on transfer to the aircraft. Those in the zero landing trials group received instrument training, but no visual display. The performance criterion was the number of attempted landings prior to solo in the operational aircraft. They reported that students who

trained using low detail had better transfer compared to those using moderate detail. Further, augmented guidance enhanced transfer for low detail scenes but degraded transfer for high detail scenes.

In summary, simulators were shown to be useful for training landing skills. As the number of simulated sorties increased, performance increased, but this gain appeared to level off after approximately 25 missions. Field of view, as well as the presence or absence of crosswinds, had no significant effect on transfer. The results concerning scene detail are unclear. In some instances, greater detail led to better performance, while in other instances, it did not.

Radial Bombing Accuracy. While a majority of the research has centered on landing skill acquisition, a few studies have been conducted to determine the feasibility of training bombing missions in the simulator. For example, Lintern et al. (1987) manipulated scene content and augmented feedback in a quasi-transfer training study of air-to-ground attack skills. Participants received training using one of three scene detail levels. Final performance was based on simulated bombing missions in the simulator. They found that dive pitch error was reduced as scene detail increased. In addition, augmented feedback aided inexperienced pilots with dive pitch control and more experienced pilots with longitudinal bombing error.

Lintern et al. (1989) examined the influence of scene detail, field of view, and number of simulator trials on performance in an air-to-ground mission (i.e., radial bombing accuracy). As with Westra et al (1986), scene detail and field of view had no significant effect on performance. However, bombing accuracy improved as a result of simulator training. Lintern et al. noted that no additional improvement in bombing accuracy was achieved after 24 simulator sorties.

Instrument and Flight Control. Simulators are often used for training instrument and contact flight in beginning training. Pfeiffer et al. (1991) evaluated transfer of simulated instrument training to instrument and contact flight for a limited set of maneuvers involving turn and speed change. Participants completed eight simulator flights followed by two aircraft flights. Simulator and aircraft performance measures consisted of deviations from assigned airspeed, attitude, and heading. Results indicated positive transfer from the simulator to the aircraft. A test of the validity of simulator performance for predicting actual flight performance showed mean performance in the simulator to be strongly related to both instrument ($r = .98$) and contact ($r = .95$) flight.

Goettl (1995) used a backward quasi-transfer technique to determine transfer effects of part-task training to complex flight control tasks. Participants were assigned to one of three training groups. The first group received whole-task training, the second received part-task training concentrating on the critical task components, and the third group received part-task training on the noncritical task components. Final performance was measured in the simulator using four slalom courses (i.e., two easy and two difficult courses), where participants had to fly through "gates in the sky." The groups who received part-task training on the critical components and the group who received whole-task training did not differ in performance, while those who received non-critical part-task training performed significantly worse.

Both studies suggest that simulators provide an effective means to train instrument procedures and flight control. The results suggest that in order to produce transfer to the aircraft it may be necessary to train only the critical components of the task rather than the whole task. This has implications for simulator design and the development of simulator training syllabi.

PROBLEM AREAS

Evaluation of the transfer of training literature is difficult for many reasons. Typically, researchers fail to report sufficient detail regarding research methods (e.g., assignment of participants to control and experimental groups, reasons for loss of participants, methods used to estimate interrater agreement), training characteristics (e.g., general training features, instructor variables, student variables, training program), and simulator fidelity characteristics (Hays et al., 1990). These problems have not been resolved in the last ten years. For example, Jorna, Van Kleef, and de Boer (1992) noted that the mission requirements often are not well understood, making it difficult to design an adequate training syllabus for the simulator and identify a measure of performance. According to Taylor et al. (1993), the development and implementation of design principles to facilitate maximization of training transfer and cost effectiveness have not been well established.

In addition to these methodological concerns, this literature suffers from the lack of true simulator-to-aircraft transfer studies involving complex pilot skills. This may be due to a number of reasons including inadequate simulator design, cost, and availability and access to simulators in operational flying units.

FUTURE DIRECTIONS

Recent developments in technology have led to advances in simulator design. For example, faster, more powerful computers make it possible to link several simulators together to create a virtual multiship environment. Pilots are now able to fly four-ship sorties against multiple adversaries in near real time. In addition, the simulator visual systems have improved in that more realistic terrain mapping is now possible.

Given the current status of simulator design, it is now possible to investigate a wide range of flying skills in both novice and experienced pilots. Future studies will be able to address issues such as complex skill acquisition and group performance involving multiship scenarios.

REFERENCES

Goettl, B. P. (1995). Part-task training of complex tasks. In *Proceedings of the 39th Annual Meeting of the Human Factors and Ergonomics Society*, San Diego, CA, 1345-1349.

Hays, R. T., Jacobs, J. W., Prince, C., & Salas, E. (1992). Requirements for future research in flight simulation training: Guidance based on a meta-analytic review. *The International Journal of Aviation Psychology, 2,* 143-158.

Jorna, P.G., Van Kleef, E. R., & de Boer, W. P. (1992). *Aircraft simulation and pilot proficiency: From surrogate flying towards effective training* (NLR-TP-91489-U, AD-B179 300). Amsterdam, Netherlands: National Aerospace Laboratory.

Lintern, G., & Garrison, W. V. (1992). Transfer effects of scene content and crosswind in landing instruction. *The International Journal of Aviation Psychology, 2,* 225-244.

Lintern, G., Roscoe, S. N., Koonce, J. M., & Segal, L. D. (1990). Transfer of landing skills in beginning flight training. *Human Factors, 32,* 319-327.

Lintern, G., Roscoe, S. N., & Sivier, J. E. (1990). Display principles, control dynamics, and environmental factors in pilot training and transfer. *Human Factors, 32,* 299-317.

Lintern, G., Sheppard, D. J., Parker, D. L., Yates, K. E., & Nolan, M. D. (1989). Simulator design and instructional features for air-to-ground attack: A transfer study. *Human Factors, 31,* 87-99.

Lintern, G., Taylor, H. L., Koonce, J. M., Kaiser, R. H., & Morrison, G. A. (1997). Transfer and quasi-transfer effects of scene detail and visual augmentation in landing training. *The International Journal of Aviation Psychology, 7,* 149-169.

Lintern, G., Thomley-Yates, K. E., Nelson, B. E., & Roscoe, S. N. (1987). Content, variety, and augmentation of simulated visual scenes for teaching air-to-ground attack. *Human Factors, 29,* 45-59.

Pfeiffer, M.G., Horey, J.D., & Butrimas, S.K. (1991). Transfer of simulated instrument training to instrument and contact flight. *The International Journal of Aviation Psychology, 1,* 219-229.

Taylor, H. L., Lintern, G., & Koonce, J. M. (1993). Quasi-transfer as a predictor of transfer from simulator to airplane. *The Journal of General Psychology, 120,* 257-276.

Westra, D. P., Lintern, G., Sheppard, D. J., Thomley, K. E., Mauk, R., Wightman, D. C., & Chambers, W. S. (1986). *Simulator design and instructional features for carrier landing: Transfer study* (NAVTRASYSCEN TR-85-C-0044-2, AD A169 962). Orlando, FL: Naval Training Systems Center.

Wightman, D. C., & Sistrunk, F. (1987). Part-task training strategies in simulated carrier landing final-approach training. *Human Factors, 29,* 245-254.

APPENDIX : RELATED REFERENCES

Andre, A. D., Heers, S. T., & Cashion, P. A. (1995). Effects of workload preview on task scheduling during simulated instrument flight. *The International Journal of Aviation Psychology, 5,* 5-23.

Baltzley, D. R., Kennedy, R. S., Berbaum, K. S., Lilenthal, M. G., & Gower, D. W. (1989). The time course of postflight simulator sickness symptoms. *Aviation, Space, and Environmental Medicine, 60,* 1043-1048.

Brooks, R. B. (1985). *Radar warning receiver special function trainer: Preliminary Evaluation (*AFHRL-TP-84-59, AD A155302). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Best, P. S., & Schopper, A. W. (1995). *Effects of system delay on aviator-related performance* (CSERIAC-RA-95-011, AD B206 998L). Wright-Patterson AFB, OH: Crew System Ergonomics Information Analysis Center.

Bruce, P. D. (1989*). Aircrew training evaluation: B-52 and KC-135 formal school training* (AFHRL-TR-88-49, AD A208 860). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Canaras, S. A., Gentner, F. C., & Schopper, A. W. (1995). *Review & analysis: Virtual reality (VR) training* (CSERIAC-RA-95-009, AD B220 892L). Wright-Patterson AFB, OH: Crew System Ergonomics Information Analysis Center.

Cass, J. R., & Reed, S. E. (1993). *T-1A simulator qualification operational test and evaluation (QOT&E): Final report,* (AFOTEC/TR-91-008, AD B172 975L). Kirtland AFB, NM: Air Force Operational Test and Evaluation Center.

Clapp, J. K., Holck, E. K., Williams, D. L., Tomlin, E. H., & Borchers, L. W. (1985). *F-16 weapon system trainer qualification operational test and evaluation,* (AD B096 204L). Kirkland AFB, NM: Air Force Operational Test and Evaluation Center.

Connolly, T. J. (1990). *Pilot decision-making training,* (AFHRL-TP-88-67, AD A221 349). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Connolly, T.J., Blackwell, B.B., & Lester, L.F. (1989). A simulator-based approach to training in aeronautical decision making. *Aviation, Space, and Environmental Medicine, 60,* 50-52.

Cyrus, M.L. (1978). *Motion systems role in flight simulators for flying training* (AFHRL-TR-78-39, AD A059 744). Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory.

Dixon, K. W., & Curry, D. G. (1990). *Weapons delivery training: Effects of scene content and field of view* (AFHRL-TP-88-29 AD A227 968). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Dixon, K. W., Krueger, G. M., Rojas, V. A., & Martin, E. L. (1990). *Visual behavior in the F-15 simulator for air-to-air combat (*AFHRL-TP-89-75, AD A218 648). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Dixon, K. W., Martin, E. L., Rojas, V. A., & Hubbard, D. C. (1990). *Field-of-view assessment of low-level flight and an airdrop in the C-130 weapon system trainer (WST)* (AFHRL-TR-89-9, AD A218 504). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Edwards, B. J. (1986). *Low-cost avionics simulation for aircrew training* (AFHRL-TR-85-38 (AD A169 198). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Edwards, B. J. (1987). *Aircrew task surveys: Selection criteria for low-cost training technology applications* (AFHRL-TP-86-52, AD A178 473). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Edwards, B. J. (1993). *Lessons learned from the development and transition of the air intercept trainer (AIT)* (AL/HR-TR-1993-0157, AD A274 558). Mesa, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Gordy, G. H. (1987). *F-16 weapons system trainer (WST) FOT&E: Final report* (AD B114 852L). Eglin AFB, FL: Tactical Air Warfare Center.

Graham, D. B. (1986). *Test plan: NOVOVIEW SP3T (SMK-117) visual system operational test and evaluation* (AD-B109 262L). Randolph AFB, TX: Air Training Command.

Hinton, W. R. (1993). *F-16 multi-task trainer special project: Final report* (AD B171 521L). Tucson, AZ: Air National Guard/Air Force Reserve Test Center.

Holder, K. D., Dyer, D. D., Marshall, G. W., Sonnenburg, J. W., & Tomlin, E. H. (1987). *EF-111A operational flight trainer initial operational test and evaluation (IOT&E) final report* (AFOTEC-0172, AD B112 162L). Kirkland AFB, NM: Air Force Operational Test and Evaluation Center.

Jacobs, J. W., Prince, C., Hays, R. T., & Salas, E. (1990). *A meta-analysis of the flight simulator training research* (NAVTRASYSCEN TR-89-006). Orlando, FL: Human Factors Division, Naval Training Systems Center.

Killion, T. H. (1986). *Electronic combat range training effectiveness* (AFHRL-TR-86-9, AD B104-833L). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Killion, T. H., Boyle, G. H., & Eaton, B. J. (1987). *Common computer-based training systems: A recommended approach* (AFHRL-TP-86-61, AD A182 770). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Killion, T. H., Boyle, G. H., & Edwards, B. J. (1987). *Electronic combat part-task training: Reasons and recommendations* (AFHRL-TP-86-50, AD B108 662L). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Knerr, C. M., Morrison, J. E., Mumaw, R. J., Stein, D. J., Sticha, P. J., Hoffman, R. G., Buede, D. M., & Holding, D. H. (1986). *Simulation-based research in part-task training* (AFHRL-TR-86-12, AD B107 293L). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Koonce, J. M., & Lintern, G. (1991). Visual augmentation and scene detail effects in flight training. In *Proceedings of the 6th International Symposium on Aviation Psychology,* Columbus, OH, 811-816.

Kroeker, S. H. (1989). *GBU-15 part task trainer IOT&E (initial operational test and evaluation)* (AD B136 456L). Eglin AFB, FL: Tactical Air Warfare Center.

Lake, L. (1989). *KC-130 operational flight trainer (Device 2F152) flying qualities and performance flight fidelity evaluation: Final report* (NATC-FW-37R-89, AD B138 075L). Patuxent River, MD: Naval Air Test Center.

Lee, A. T., & Bussolari, S. R. (1989). Flight simulator platform motion and air transport pilot training. *Aviation, Space, and Environmental Medicine, 60,* 136-140.

Marcus, A. J., & Curran, L. E. (1988). *The use of flight simulators in measuring and improving training effectiveness* (CRM-86-27, AD A171 661). Alexandria, VA: Center for Naval Analyses, Naval Planning Manpower and Logistics Division.

Martin, E. L. (1981). *Training effectiveness of platform motion: Review of motion research involving the advanced simulator for pilot training and the simulator for air-to-air combat* (AFHRL-TR-79-51, AD A095 930). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Martin, E. L., & Waag, W. L. (1978). *Contributions of platform motion to simulator training effectiveness: Study I - Basic contact* (AFHRL-TR-78-15, AD A058 416).Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory.

Martin, E. L., & Waag, W. L. (1978). *Contributions of platform motion to simulator training effectiveness: Study II - Aerobatics* (AFHRL-TR-78-52, A064 305). Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory.

Mattoon, J. S. (1994). *Instructional control and part/whole-task training: A review of the literature and experimental comparison of strategies applied to instructional simulation* (AL/HR-TR-1994-0041, A280 860). Mesa, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Mattoon, J. S., & Edwards, B. J. (1993). *Theoretical implications and empirical findings on instructional control and part-whole-task training,* AL/HR-TR-1993-0089, AD A267 826. Mesa, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Moor, W. C., & Andrews, D. H. (1992). *Benefit-cost model for the evaluation of simulator-based multiship training* alternatives (AL/HR-TP-1992-0023, AD A253 039). Williams AFB, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Moor, W. C., & Andrews, D. H. (1993). *Benefits estimation for simulation systems used for aircrew training in a multiship environment* (AL/HR-TR-1993-0158, AD A274 313). Mesa, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Mowafy, L., & Miller, L. (1993). *Visualizing spatial relationships: Training fighter pilots in a virtual environment debrief interface* (AL/HR-TR-1993-0148, AD A273 972). Mesa, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Pfeiffer, M. G., & Dwyer, D. J. (1991). *Training effectiveness of the F/A-18 weapon tactics trainer (Device 2E7)* (NTSC-TR-91-008 AD B160 186L). Orlando, FL: Naval Training Systems Center.

Polzella, D. J., Hubbard, B. C., Brown, J. E., & McLean, H. C. (1987). *Aircrew training devices: Utility and utilization of advanced instructional features (Phase IV – Summary report)* (AFHRL-TR-87-21, AD A188 418). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory

Pultz, J. T. (1991). *F-111E/F mission simulator (MS) and EF-111A operational flight trainer (OFT) block update number one (Bun 1) QOT&E test plan.* Eglin AFB, FL: Tactical Air Warfare Center.

Rasinski, J. E., Rabeni, J. J., Holck, E. K., & Pierce, B. (1983). *A-10 operational flight trainer phase 1 follow-on operational test and evaluation final report* (81-AFOTEC-213). Kirkland AFB, NM: Air Force Operational Test and Evaluation Center.

Reid, G. B., & Cyrus, M. L. (1977). *Formation flight trainer evaluation for T-37 UPT* (AFHRL-TR-77-23, AD A043 197). Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory.

Rolfe, J. M., Cook, J. R., & Durose, C. G. (1986). Knowing what we get from training devices: Substituting a little arithmetic for a little emotion. *Ergonomics, 29,* 1415-1422.

Ryder, J. M., Beckchi, R. G., Redding, R. E., & Edwards, B. J. (1988). *Modern trainingmodel concepts for aircrew training* (AFHRL-TR-87-34, AD-B123 809L). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Szpila, G. E., Salmon, S. M., & McCaffery, T. S. (1994). *Accomplishing C-5 training events in the Westover Air Reserve Base weapon system trainer: FOT&E final report* (AD-B186 629L). Charleston AFB, SC: Air Force Mobility Center.

Szymczak, M. A. (1986). *B52 combat readiness: How long between flights?* (ACSC-86-2485, AD-B102 356). Maxwell AFB, AL: Air Command and Staff College.

Thomas, G. S., Houck, M. R., & Bell, H. H. (1990). *Training evaluation of air combat simulation* (AFHRL-TR-90-30, B145 631L). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Ungs, T. J. (1989). Simulator induced syndrome: Evidence for long-term aftereffects. *Aviation, Space, and Environmental Medicine, 60,* 252-255.

Waag, W. L. (1988). Programs and prospects in aircrew performance measurement. *Aviation, Space, and Environmental Medicine, 59,* A46-A51.

Whitley, S., & Traven, R. (1993). *F/A-18 simulation validation and verification—making a good product even better* (AD A283 995). Patuxent River, MD: Naval Air Warfare Center, Aircraft Division.

Woodruff, R. R., Hubbard, D. C., & Shaw, A. (1985). *Advanced simulator for pilot training and helmet-mounted visual display configuration comparisons* (AFHRL-TR-84-65, AD A155 326). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

Wray, D. W. (1987). Computer assisted part-task trainers in aircrew training (NDU/ICAP-87-S59, AD B115 949L). Washington, DC: The Industrial College of the Armed Forces.